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Potential of Construction and Demolished Wastes as Pozzolana

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Abstract

The construction and demolition (C&D) wastes constitute 25% of the solid waste generation in India. A large proportion of these wastes are disposed off as landfill leading to severe social and environmental problems. Environmental considerations are pushing the industry towards more sustainable practices which leads less energy intensive blended cements in construction. This paper examines the possibility of using the finely ground C&D wastes as cementitious material. The C&D wastes are categorised as processing waste and demolition waste. The processing wastes used in this study are saw dust ash and roof tile powder. The demolition wastes used for this study are concrete waste and laterite waste. The results obtained confirmed the pozzolanic activity of both processing waste and demolition waste.

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Keywords: Construction and Demolition (C&D) wastes; cementitious material ;Pozzolana.

1. Introduction

The cost of construction materials is increasing day by day due to high demand, scarcity of raw materials and high price of energy. In India, the cost of cement during 1995 was Rs 1.25/ kg and in 2005 the price increased to three times. (P.Asokan et al, 2012;). Now, the cost of cement is increased to eight times. Ordinary Portland cement (OPC) is currently under discussion not only for its cost but also for its environmental effects during manufacture. The

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production of 1 ton of OPC supposes the consumption of 1.4 tonnes of quarry material, energy consumption of 5.6 GJ/ton and an emission of nearly 0.9 ton of CO_2, representing 5% of total anthropogenic CO_2 emission. (Reddy et al.,2006;). Currently manufacturers find it difficult to locate adequate sources for raw materials. The raw materials have been produced from the existing natural resources and will have intrinsic damage to the environment due to their continuous exploitation.

Moreover, a huge quantity of solid waste is being generated annually during construction, mining, municipal, agricultural and other processes which leads to a major source of pollution. It is estimated that about 14.5 million tonnes of solid wastes are generated annually from construction industries alone, which includes the unwanted left over material from any construction activity which can be new construction, renovation and demolition. (Saxena et al. 2008). The disposal of construction and demolition (C&D) wastes has become a severe social and environmental problem in our country. The environmental and economic implications of this are no longer considered sustainable and, as a result, the construction industry is experiencing more pressure than ever before to overcome this practice. This negative impact can be reduced through recycling. The possibility of recycling of waste from the construction industry is thus of increasing importance. Perhaps, demolition waste is a viable option to decrease the demand on high quality natural resources and to limit the amount of waste that is disposed in landfills.

From the standpoint of energy saving and conservation of natural resources, the use of alternative constituents in construction materials is now a global concern. For this, the extensive research and development works towards exploring new ingredients are required for producing sustainable and environment-friendly construction materials.

Significant research studies have been conducted on the development of new construction materials from construction and demolition wastes. The C&D wastes such as ceramic waste powder, saw dust ash, glass powder, brick powder, concrete powder, timber powder has pozzolanic properties. (Elinva et al., 2004; Augustine et al., 2002; Osman et al., 2010;Naceri et.al.,2007;).

The C&D wastes are categorised as processing waste and demolition waste. The present study investigates the potential use of various C&D wastes as cementitious material. Due to the availability and ease of processing as fine material, the processing waste used in this study are saw dust ash (SDA) and roof tile powder (RTP). The demolition wastes used for this study are waste concrete powder (WCP) and waste laterite powder (WLP).

2. Experimental Programme

The C&D wastes used for the study were subjected to material characterization and test on pozzolanicity.

2.1.Materials and methods

2.1.1. Saw Dust Ash

Sawdust was collected from a saw mill at Edavoor, Ernakulam district of Kerala. Then it is dried under sunlighmicrt, ground and sieved through 90 micron IS sieve to get sawdust powder of size equivalent to that of cement. Then, it was burnt in an annular kiln to get saw dust ash .

2.1.2. Roof Tile Powder

The rejected roof tile waste from a tile manufacturing unit at Muringoor, Trichur district of Kerala was collected, crushed and sieved through 90 micron IS sieve.

2.1.3. Waste Concrete Powder

Waste concrete powder was produced by crushing the concrete waste of a demolished builing 30 years old (R.C.C roof slab waste) crushed in a Los angeles apparatus and sieved through 90 micron IS sieve.

2.1.4. Waste Laterite Powder

Waste laterite powder was collected from an old demolished structure which was 30 years old. The samples were collected and crushed in a ball mill and then sieved through 90 micron IS sieve.

2.2. Material Characterization

The table 1 shows the material characterization of selected C&D wastes.

Table 1. Material characterization.

C & D wastes	Specific Gravity (g/cm^3)	Standard Consistency (%)	Initial Setting Time(minutes)	Final Setting Time (minutes)	Fineness (retained on 90µm in %)
SDA	1.485	39	110	320	7%
WLP	2.857	30	220	410	14%
WCP	2.489	36	65	10	14%
RTP	3.490	34	85	210	9%
OPC	3.010	30	115	195	4%
IS Specifications	3 – 3.15		Not less than 30 minutes	Not more than 600 minutes	Less than 10%

2.2.1. Chemical Analysis

A comparison of chemical properties of C&D wastes are shown in table 2

Table 2. Chemical properties of OPC and C&D wastes

Chemical Oxide Composition (% wt)	SDA	WLP	WCP	RTP	OPC	ASTM C 114
SiO_2	16.5	37	44.4	62.8	31	-
Al_2O_3	12.9	15.75	7.5	12.9	10.6	Min 0.66
Fe_2O_3	43	14.25	4.5	4.7	4.6	Max 1
CaO	47.2	14.88	23.8	47.2	42.5	-
SO_3	2.7	1.1	0.39	2.7	2.1	Max 3
MgO	4.7	1.2	3.3	4.7	2.2	Max 6
Insoluble residue	7.3	5.7	7.3	7.3	2.3	Max 2
Loss on Igniion	5	3.4	4.1	5.4	5.6	Max 10
Free Moisture Content	-	6.76	4.35	-	1.5	Max 3
Color	Blackish grey	Orange red	Light grey	Dark red	Light grey	

2.2.2. *Chemical properties required for Pozzolanas*

Table 3. Chemical properties required for pozzolana

Materials	RTP (%)	SDA (%)	WCP (%)	WLP (%)	ASTM C 618
(SiO_2+Al_2O_3+Fe_2O_3), min%	80.4	72.4	56.4	67.0	> 70
(SO_3), max %	1.70	2.70	0.39	1.10	< 3.0
Moisture Content, max %	4.35	6.76	-	-	< 3.0
Loss on Ignition, max %	2	5	14	13	< 10

3.Test On Pozzolanicity

The following tests were conducted to establish the potential of C&D wastes as pozzolanic material.

3.1 Specific surface area

The specific surface area was evaluated using BET (Brunauer, Emmett and Teller) method according to IS 1727-1967. The values are tabulated in table 4.

Table 4. Specific surface area of C&D wastes

Materials	Surface Area (m^2/kg)
SDA	415
WLP	324
WCP	318
RTP	404
OPC	341

3.2 Determination of lime reactivity

Lime reactivity test was conducted as per IS 3812:2003. Cube specimens of size (70 mm x 70 mm x 70 mm) were prepared and tested. The specimens were cured at 90 to 100% relative humidiy at 50°C and tested. The 28 day compressive strength was found and the values are tabulated in table 5.

Table 5. Lime reactivity of C&D wastes

Materials	Strength Index (N/mm^2)	As per IS 3812:2003
SDA	5.50	
WLP	1.64	
WCP	2.61	
RTP	6.30	4.5 N/mm^2

3.3 Scanning Electron Microscopy Test

A scanning electron microscope (SEM) analysis was conducted on C&D to obtain information about the surface topography and composition.

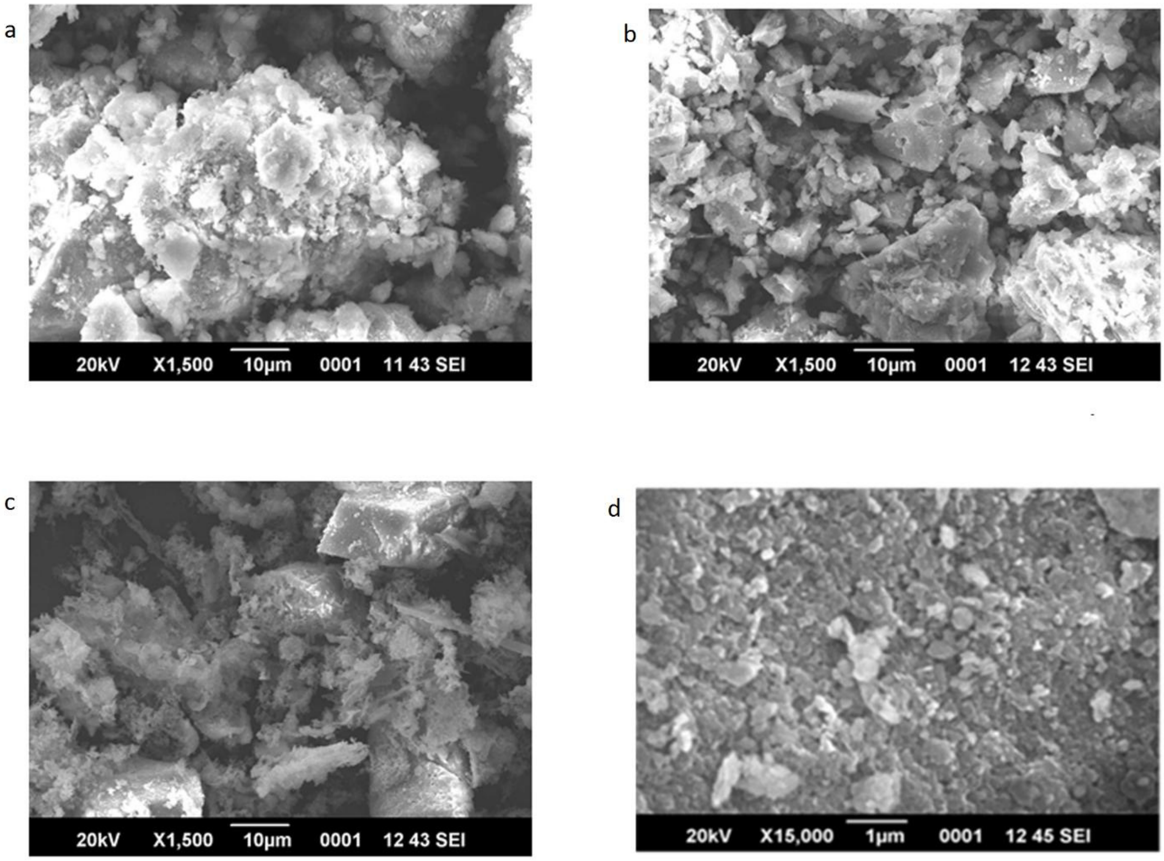

Fig 1. SEM images of C&D wastes (a) Waste laterite powder; (b) Waste Concrete powder; (c) Saw dust ash; (d) Roof tile powder.

3.4 Soluble Fraction of Silica

All samples were subjected to chemical analysis for the determination of soluble fraction of silica according to ASTM C 311-00 Standards. Table 6 shows the results.

Table 6. Percentage of soluble fraction of silica of C&D wastes

Materials	Percentage of Soluble Silica
SDA	69.7
WLP	66.51
WCP	63.28
RTP	73.05

3.5 Electrical Conductivity

The variation in electrical conductivity of saturated calcium hydroxide solution on dispersing with the C&D waste samples can be taken as a measure of the pozzolanic activity of the samples (Luxan et.al., 1989). It is based up on the concept that the active constituents of the pozzolanic material will react with calcium hydroxide leading to a decrease in concentration of Ca^{2+} and hence to a decrease in electrical conductivity. Table 7 illustrates the pozzolanic activity of different C&D samples by the changes in electrical conductivity.

Table 7. Electrical conductivity of C&D wastes

Materials	Variation in electrical conductivity (Pozzolanicity ms/cm)
SDA	1.382
WLP	0.240
WCP	0.207
RTP	1.291

4. Results And Discussions

This section presents the discussion of the results of the experimental programme.

4.1. Chemical Analysis

The chemical composition of RTP and SDA as revealed by the chemical analysis satisfy the requirement of class N pozzolana (ASTM C 618) whereas other two samples (WCP and WLP) has a lower Fe2O3 and Al2O3 content showing their low pozzolanic property.results of chemical analysis of the samples met the chemical requirements for pozzolanic material with a percentage

4.2 Specific Surface Area

The higher surface area is an indication of high reactivity of the samples and thus imparts pozzolanic property. SDA and RTP samples were having higher specific surface area compared with OPC.

4.3 Lime reactivity

The lime reactivity test confirms the pozzolanic property of RTP and SDA i.e. 6.30 N/mm^2 and 5.50 N/mm^2 at 28 days where as standard value as per IS 3812 is 4.5N/mm^2. The higher value is an indication of high pozzolanicity and micro-filling effect owing to the higher surface area.

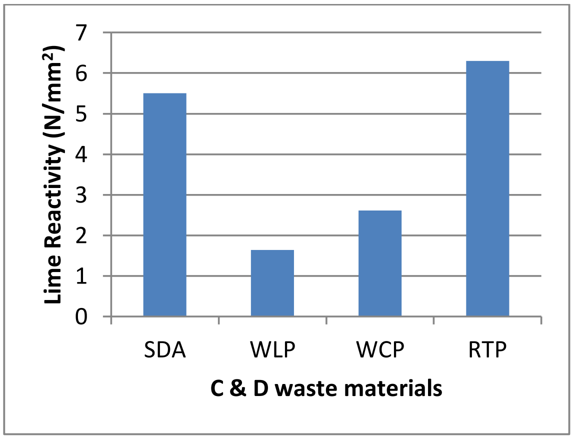

Fig 2. Lime reactivity at 28 days

4.4 Scanning electron microscopy

The result of scanning electron microscopy of the samples shows that RTP has numerous fine particles with sizes of approximately 1 µm. The surface texture is homogeneous and spherical. Finer particles are traced in RTP compared to other samples which confirms the pozzolanic activity of the material.

4.5 Soluble fraction of silica

Different C&D samples were subjected to chemical analysis for amorphous silica. Among the four samples, RTP sample has the highest soluble silica fraction and WCP has the lowest value.

4.6 Electrical conductivity

The results of electrical conductivity shows that both RTP and SDA samples gave large conductivity changes which can be interpreted as good value for pozzolanic activity. On the basis of these experiments both RTP and SDA samples qualify as good pozzolanas. According to Luxan et.al ; (1989) variation in electrical conductivity more than 1.2 is referred as good pozzolana.

5.Conclusions

1. The results of this experimental investigation proved the potential of RTP and SDA as pozzolanic materials.
2. The demolished wastes (WCP and WLP) used for the study is having inferior pozzolanic property compared with SDA and RTP owing to their chemical composition. These results are justified by the lower values of lime reactivity and electrical conductivity.

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